THE POLLUTION OF UNDERGROUND WATERS.

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THE source of water for domestic purposes might be divided into three classes: First, waters secured from streams or lakes; second, impounded surface waters, as ponds, cisterns, etc.; third, the ground waters, such as wells and springs. The latter is by far the greatest source of supply to the people of this country, and it is to the discussion of the pollution of this class of water that I desire to direct your attention.

The amount of ground water in the earth's crust is enormous. An estimate made by DeLesse—based on the assumption that the water in rocks diminished from 5 per cent of their weight, or 12½ per cent of their volume at the surface, to nothing at a depth of six miles, and that water may exist in liquid form at a temperature of 600° C.—gave a sheet of water over 7500 feet thick surrounding the earth.

Slichter made an estimate of less than half that of DeLesse, which estimate was equivalent to a uniform sheet of water 3000 feet in thickness.

Van Hise's guess was 226 feet of water over the continental areas, no computation being made regarding the oceanic areas.

Chamberlain and Salisbury, assuming a porosity of 5 per cent for the soil, estimated a layer of water 1600 feet in depth covering the entire surface.

Myron L. Fuller, of the United States Geological Survey, after making an extensive investigation and experiments as to the porosity of soil and rock in this country, together with the thickness of sediments, and the evidence of circulation of free water in the earth's crust, came to the conclusion that the total free water held in the earth's crust would be equivalent to a uniform sheet over the entire surface of a depth of ninety-six feet. The underground water would, therefore, be estimated to be only one one-hundredth of the volume of the ocean, instead of nearly one-half, as figured by DeLesse. Fuller finally concludes that the average amount of water in the earth is probably under, rather than over, the amount estimated.

Comparatively little of this ground water is available for the purpose of a domestic water supply, for reasons which are self-evident. First, probably a larger share of it carries such quantities

of chlorine or minerals as to make it unsuitable; and second, the greater portion of it is at such depths as to be beyond the reach of economic production. It is only that portion of the ground water coming from springs, or that is available by comparatively shallow wells, which has any sanitary significance, and to which we will confine our discussion.

Ordinarily the amount of ground water available in a community depends upon the annual precipitation. The mean annual average rainfall for the different portions of the United States, as tabulated by the weather bureau, is thirty inches.

Church estimates that one inch of rain would amount to nearly 101 gross tons per acre; or, on a house roof of say 20x30, one inch of rain would amount to about 374 gallons.

Some one has estimated that one-half of the precipitation finds its way into the streams, finally joining the great ocean. This would give the remaining half of this tremendous annual precipitation to be absorbed by the soil or given off by evaporation.

It is commonly believed by the majority of laymen that rain water is an absolutely pure water, but this belief is erroneous; for the raindrops in passing through the atmosphere wash out and collect enormous quantities of dust, smoke and gases, so that, bacteriologically speaking, it is exceedingly doubtful whether any rain water is absolutely pure. It is probably true that there would be very little, if any, pollution of rain water to the extent of making it a dangerous pollution.

As soon as the rain falls upon the earth it of necessity comes in contact with the gross pollution of the top layers of the soil, which some one has denominated "the living earth," and which, as everyone knows, is teeming with myriads of all sorts of germ life. In the inhabited areas this pollution is of a dangerous sort, as would naturally be expected.

With the descent of the rain drops into the soil there is carried with it more or less organic and inorganic matter, soluble and insoluble, and myriads of living and lifeless organisms. As the water sinks deeper and deeper into the porous soil the insoluble matters, as well as the bacterial contents, are gradually filtered out; the rapidity and degree of filtration depending, of course, on the nature and porosity of the soil. As the filtration process goes on, the water, being robbed of its organic matter, becomes the less able to support abundant bacterial life.

The average soil under ordinary and uncontaminated conditions is supposed to be practically sterile at a depth of twelve feet; at

least sufficiently so for all sanitary purposes. Thus the great mass of rainfall, although grossly polluted when first finding its way through the top layer of soil, under ordinary conditions is of a high sanitary quality after having passed through ten or twelve feet of soil. These waters, while of a high organic purity, become in many places rich in inorganic matters and belong to the class known as hard, or mineral waters; in many cases being so highly loaded with sulphates, chlorides or carbonates as to be unfitted for domestic use.

On the other hand, ground waters may be basely polluted, instead of purified, when they are on their passage through the earth. If the earth is saturated with impurities, as may occur from leaching cesspools, privy vaults, sink drains, barnyards, burying grounds, or other sources of pollution, nature's purifying operations may give way to one of intense pollution.

Wells whose source of supply is from the so-called first stratum of water, in the densely populated communities along the Arkansas river and the Kaw river and its tributaries, are peculiarly susceptible to this form of ground-water pollution. The first stratum of water is usually from eight to fifteen feet from the surface, with an exceedingly porous and sandy soil intervening, and thus any unusual or great amount of pollution overtaxes the purifying and filtration properties of this soil, and there is a resulting contamination of the underground water.

The prosperity of the people in the smaller communities and towns of the state is perhaps no better reflected than in the movement to improve and modernize their homes. This calls for some method of sewage disposal, and, in the absence of a sewerage system, the disposal usually resorted to is the construction of the cesspool, and, in some instances, the use of an abandoned well. Thus in the river valleys above referred to the ground water may be and often is very badly polluted.

Recently it was suspected that a cesspool situated about 150 feet to the west of a well, in a certain city on the Smoky Hill river, was polluting the underground water. In order to determine whether or not the liquid contents of the cesspool was finding its way into the well, a solution of iron sulphate was put into the cesspool, and in about forty-eight hours the people who were using the waters of the well were able to identify the astringent and bitter taste of the iron. Chemical and sanitary analyses of the waters of this well proved, what the solution of iron sulphate had already

proven, that the users of the water from the well were drinking the diluted sewage of their neighbor's cesspool.

It is true that this sewage would for a considerable period of time be to a greater or less extent purified, that is to say, would not contain any pathogenic organism; yet as time goes on the degree of pollution, as well as the area of pollution, gradually increases, until it would seem to be entirely possible for disease to be transmitted in this manner. At all events there are few of us who have the desire to drink the sewage of our neighbors, notwithstanding we may have the scientific assurance that it is perfectly harmless.

Another illustration of this sort of pollution occurred at the sugar refinery at Garden City. Tons and tons of beet pulp were heaped upon the ground, for the want of a better place of storage, and was allowed to remain for a number of months, much of it undergoing fermentation and decomposition. In the spring this beet pulp was disposed of and the ground thoroughly cleansed of all of the pulp. Yet for a number of months afterwards a series of wells, which had been constructed by the sugar company at a point several hundred feet east of the place used as a storage for the beet pulp, and which were being pumped at the rate of several million gallons of water per day, continued to throw off the vilest odors of sulphureted hydrogen gas, and deposited in the troughs which conveyed the water to the factory a thick, heavy layer of organic matter.

Another method of pollution of wells and springs is through faults or fissures of an impervious strata carrying the ground-water supply, or through which a head of water draining a polluted basin or area finds its way to the surface in the form of a spring through a fissure.

There is at least one example of this kind in Kansas. A certain city has for a number of years boasted upon the purity of its public supply, because, forsooth, it was spring water. Bacteriological tests of this water on a number of occasions showed it contaminated with colon bacillus. Careful investigation by the engineer and secretary of the State Board of Health revealed the fact that this spring was, in the main, the outlet from extensive basins and swamps located near by, and which came to the surface through a large fissure of the overlying rock.

Literature records a number of extensive epidemics of typhoid fever due to these underground breaks or fissures. In one instance, in Switzerland, an epidemic of typhoid fever broke out in a certain village, and over 17 per cent of the inhabitants were stricken. The entire village was supplied from waters of a spring. A painstaking

investigation revealed the following facts: On the other side of the ridge was a little valley which when irrigated always increased the flow of the spring on the village side of the mountain. It was found that a peasant living in the valley had returned from a distant city sick with the fever, and that the water in a brook in which his clothes had been washed and into which the slops of the house had been cast had been used to irrigate the meadow. Of course the polluted water filtered through the surface of the soil and joined the underground water to go to no one knew where. In order to determine if it could be possible that this spring was fed by the underground waters of a valley a mile away, a large quantity of salt was thrown into a hole dug into the valley to a water-bearing vein of sand, and in a few hours the waters of the spring became very salty, and thus was established the connection between the irrigated valley and the spring.

To conclude that because water is bright, clear and sparkling, that therefore it is wholesome, is highly erroneous. The very gases of decomposition may make a sparkling water, and but little filtration is necessary under ordinary conditions to remove turbidity. Therefore, shallow wells or springs located in densely populated areas, or in loose, porous soil, or near to known and evident sources of pollution, must be always under suspicion as to its purity and wholesomeness, regardless of its physical appearance.

Another source of pollution of wells and springs, and which, after all, is probably the most common, and certainly the most dangerous, is that of direct surface contamination, in which the polluted surface water finds its way into the well or spring without the purifying filtration of intervening layers of soil.

In this connection I desire to quote a paragraph which recently appeared in the pamphlet issued by the Merchants' Association Committee of New York which had undertaken the investigation of the cause of typhoid fever in that state:

"Great cities are developing some sort of a sanitary conscience. Farmers and country districts have as yet little or none. Bad as our city water often is, and defective as our system of sewage, they cannot for a moment compare in deadliness with the most unheavenly pair of twins—the shallow well and the vault privy. A more ingenious combination for the dissemination of typhoid than this precious couple could hardly have been devised. The innocent householder sallies forth, and at an appropriate distance from his cot digs two holes, one about thirty feet deep, the other about four. Into the shallower he throws his excreta, while upon the surface of the ground he flings abroad his household waste from the back stoop. The gentle rain from heaven washes these various products down into the soil and percolates gradually into the deeper hole. When the interesting

solution has accumulated to a sufficient depth, it is drawn up by the old oaken bucket or modern pump, and drank. Is it any wonder that in this progressive and highly civilized country 350,000 cases of typhoid occur every year, with a death penalty of ten per cent?"

It must be admitted that in locating the outbuildings and the well on the average farm or in the average small town, the bearing of such location on sanitation and hygiene is entirely disregarded, the convenience of the family only being taken into consideration; and thus the well is as often located below as above the surrounding sources of pollution, and the surface water from rains carrying house slops, barnyard drainage, and filth from the near-by privy, near to, or often actually into, the well, unless it has been constructed in such a way as to exclude surface contamination.

Not only may typhoid-fever bacteria be carried into wells and springs in this manner, but those organisms which cause digestive disturbances and serious troubles, such as diarrhea, dysentery, cholera and tuberculosis may be carried into the water used for domestic purposes. Then, again, eggs of animal parasites may be washed in from the surface, and it seems to be quite certain that many of our intestinal parasites are thus disseminated.

At the recent International Congress on Tuberculosis Dr. Samuel Dixon, health officer of Pennsylvania, called attention to the possibility of the dissemination of tuberculosis through drinking tubercular-infected water.

Rosenau has recently compiled the observations made by other investigators, and concludes that the tubercular bacillus may live and remain virulent in water for several months.

Since the danger of ingesting the tubercle bacillus is now so well established, its presence in drinking water assumes a special significance. Drinking water may, therefore, harbor a disease equally dangerous to that of typhoid fever and cholera.

Hazen some time ago formulated and enunciated the following theorem: "For every death from typhoid fever avoided by the purification of public water supplies, two or three deaths are avoided from other causes."

The habit of promiscuous spitting of a consumptive upon the ground surrounding his dwelling, on the theory that the air and sun will soon make proper disposition of the sputum, is fraught with quite as much danger to the users of an unprotected ground-water supply as would be the habit of throwing the unsterilized discharges of a typhoid-fever patient upon the ground surface about the house.

We are beginning to appreciate more and more the absolute necessity of safeguarding our water and food supply from the con-

tamination of the tubercle bacillus, if we may hope for a control of this widespread disease. We have found out that the second and third cases of tuberculosis occurring in the same family is a case of the inoculation of the well from the sick, and not that of hereditary transmission; and it is not improbable that this inoculation is very often conveyed through the medium of the domestic water supply.

In the report of President Roosevelt's Country Life Commission I find the suggestive comment: "Theoretically, the farm should be the most healthful place in which to live, but it is a fact that there are numberless farmhouses and rural schoolhouses that do not have the rudiments of sanitary arrangement. . . . The extensive spread of hookworm disease in the Gulf Atlantic states and the presence of typhoid fever and malaria in many localities is more than a regional question; it is nation-wide in importance."

Dr. Worden Stiles, in a recent pamphlet issued by the Public Health and Marine Hospital Service, made a tabulation of 366 farmhouses scattered over four southern states, and which was presumed to be representative of the conditions in those states. He found that only 115, or 31.4 per cent, were provided with privies, while 251 houses, or 68.5 per cent, had no privy. Thus a condition of theoretical maximum soil pollution was occurring in 68.5 per cent of the houses in question.

When it is considered that not only hookworm disease but typhoid fever are spread through night soil, the importance of this soil pollution becomes evident. Of course, it is understood that even when a privy is present soil pollution may occur in case the outhouse is not properly built or not properly cleaned.

Stiles goes on to say that among several thousand privies examined on farms and in various villages, the prevailing style was found to be the surface privy, open in the back. This is the poorest compromise that can be made, for not only is the danger present of contaminating the water supply in near-by wells, but soil pollution naturally occurs around the outhouse, and this is increased by the fact that chickens, dogs and hogs have access to the night soil and scatter the infectious material around.

Of the 121 public water supplies of Kansas, 89 are ground-water supplies, 4 of which are from springs and 85 from wells. In view of this large per cent of the city population, together with the greater number of our entire rural population, who are dependent for their domestic water-supply upon the underground waters, it is at once apparent that the conservation of the ground waters of the state from dangerous pollution is of state-wide importance.

Water pollution involves economic as well as public-health problems. According to the census of 1900 there were 35,379 deaths from typhoid fever throughout the United States. On an estimated mortality of 10 per cent, it is within reason to assume a yearly prevalence of 353,790 cases of this disease. If we calculated the average cost for care, treatment and loss of work to be $300, and the average value of a human life at $5000, we have a total loss in the United States of $283,320,000 from one of the so-called preventable diseases.

Applying these same figures to Kansas, we find that last year there were reported 355 deaths from typhoid fever, which, with a mortality rate of 10 per cent, would make 3550 cases, making an economic loss to the state of $2,730,000.

Add to this enormous sum the economic loss through the dissemination of other diseases which might properly be charged to the pollution of water supply, and it swells the total to amounts which are almost beyond credulity.

Surely the time has come, now that science has demonstrated these facts beyond successful contradiction, that our government, both state and national, assume such control over the natural waters of this country, both surface and underground, as will preserve the lives and health of its citizens and will stay this enormous economic waste.